Space Weather Technical Forecast

Issued on Wednesday, 06 September 2023 at 13:11 Local

This technical forecast provides a four day assessment of space weather events. The probabilities stated below are for reaching or exceeding the given levels. For more information about space weather impacts please see the Met Office Space Weather Scales https://www.metoffice.gov.uk/weather/learn-about/space-weather/uk-scales

Space Weather Forecast Headline: R1 Minor Radio Blackouts Likely 06 Sep, otherwise Chance throughout.

Analysis of Space Weather Activity over past 24 hours

Solar Activity: Solar activity has been Moderate in the past 24 hours with a couple of M-flares, with GOES16 and 18 recording a peak M1.2 flare from AR3421, near centre-disc, at 05/1945UTC. There are currently seven sunspot groups on the visible disc - the most dynamic being AR3421 and AR3423. The large and central AR3421 was responsible for the Moderate flares and continues to spread horizontally, with continued development and fading of a number of intermediate spots. Some additional magnetic complexity has emerged in recent hours, with a small delta spot forming around the centre of the region. AR3423 has shown continued growth, with multiple spots emerging, although the narrow viewing angle reduces confidence in analysis. Two new regions are in the process of emerging from the northeast limb, AR3425 and a separate small bipolar region.

A large Coronal Mass Ejection (CME) with partial halo was observed on coronagraph imagery at 05/1400 UTC, leaving the Sun from the far-side of the disc, beyond the northwest limb. Initial analysis of this feature does not show an Earth-directed component. A couple of CMEs were observed from over the western limb, but aren't expected to be Earth-directed. A smaller and slower CME was seen emerging in the southwest from a region that saw a C-class flare. This may have some Earth-directed component, with an estimated arrival time of late on Day 4 (09 Sep).

Solar Wind / Geomagnetic Activity: The solar wind environment was initially at slow-ambient levels around 380 km/s before a marked discontinuity was observed around 05/1438 UTC, with speeds rapidly increasing to around 440 km/s. This is considered to indicate the arrival of a CME that left the Sun on 01 September. Wind speeds remained at Slightly Elevated levels, 420-460 km/s, before declining back to background levels, with speeds currently around 370 km/s. The phi angle was largely weakly aligned towards the Sun (negative) at first, with brief periods aligned away from the Sun (positive), before becoming consistently away from the Sun (positive) since 06/0413 UTC. The solar wind density showed a level trend within the long term background of single-figures ppcc, before suddenly increasing to Above Average upon arrival of the CME with a peak of 17ppcc around 1930UTC. Density is currently around Average. The IMF was Weak until 05/1438 UTC at which point it jumped to Moderate, with a peak of 10nT. IMF returned to weak levels around 05/1900 UTC. The north-south component weakly fluctuated until 05/1438 UTC, and again from around 05/1900 UTC. The intervening period saw fluctuations ranging between +9/-9nT.

The net result of the above solar measures was for Quiet (Kp0-2) geomagnetic activity, then Active (Kp4) or Unsettled (Kp3) periods between 05/1500-2100 UTC.

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Energetic Particles / Solar Radiation: GOES16 high energy (greater than 10MeV) proton flux has been at Background levels throughout.
GOES16 high energy (greater than 2MeV) electron flux was predominantly at Moderate levels, increasing to High 05/1525-1720 UTC) with a peak of 1870pfu at 05/1550UTC. The associated 24-hour fluence was below the Active threshold but on a rising trend, with 4.05e7 integrated pfu observed at 06/0001UTC.

Four-Day Space Weather Forecast Summary

Solar Activity: M-class flares are Likely Day 1 (06 Sep), most likely associated with AR3421, but AR3423 is also a region to watch. There is then an ongoing Chance of M-class flares that increases slightly on Day 4 with the anticipated arrival of a returning active region, coupled with the increased complexity of AR3421 and AR3423.

Solar Wind / Geomagnetic Activity: The geomagnetic forecast is for a peak Slight Chance of Active (Kp4) intervals within the current UTC day in association with a high speed stream from CH42/+. Further coronal hole influences may see some enhancement in upcoming days, but confidence is low. The CME that emerged from the southwest may have some Earth-directed component, with an estimated arrival time of late on Day 4 (09 Sep), giving the potential for some enhancement to Active or G1 Minor Storm levels (Kp4-5). In the absence of further CMEs, activity should remain largely Quiet to Unsettled (Kp0-3).

Energetic Particles / Solar Radiation: High energy (greater than 10 MeV) proton flux is Expected to remain at Background levels.

High energy (greater than 2 MeV) electron flux carries high uncertainty, and although an initial rise in diurnal flux is likely, this should soon be attenuated at GEO. Any recovery is low confidence, but on balance should perhaps most likely remain below Active throughout.

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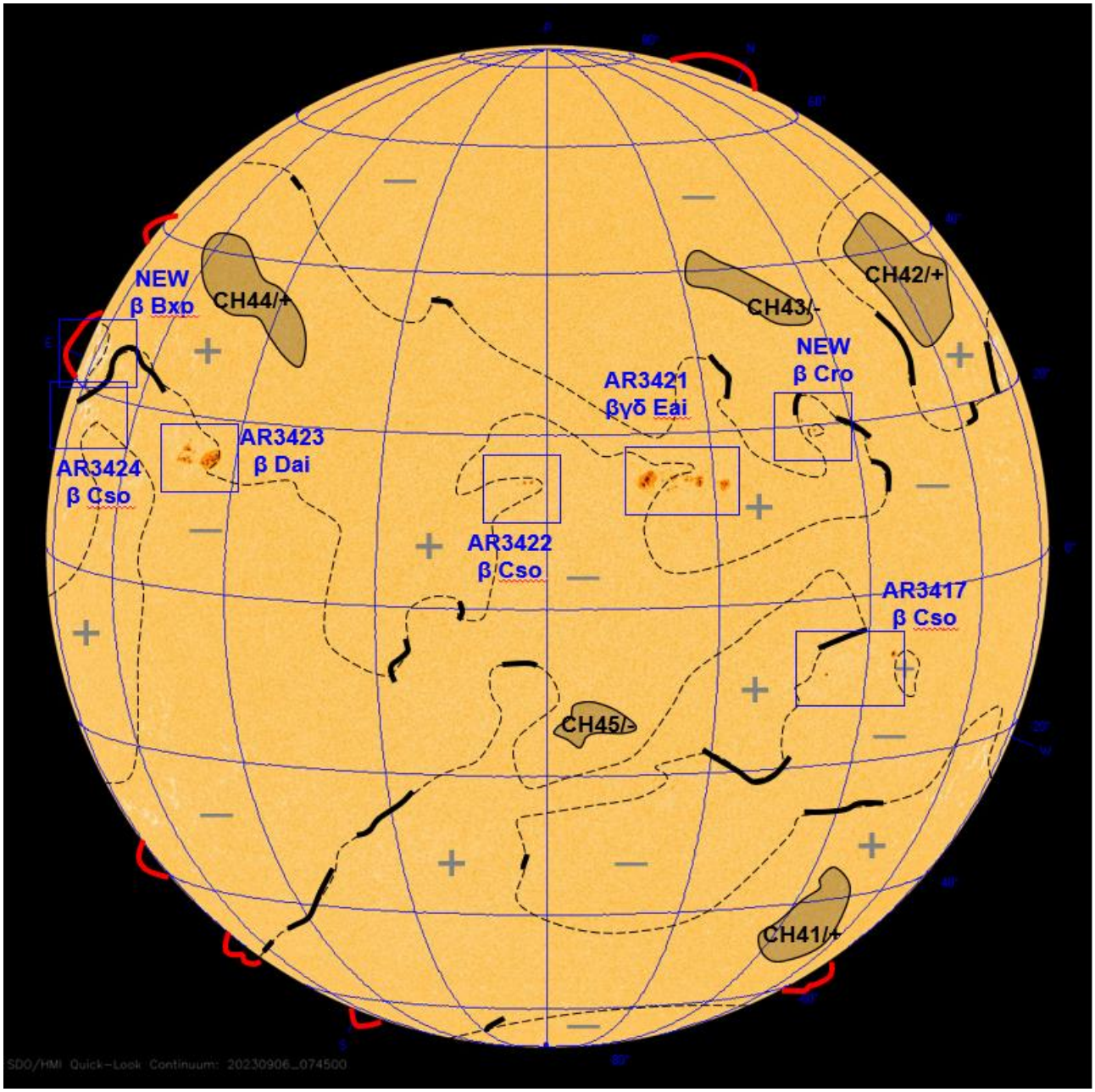
Figure 1. Solar Analysis Valid 06/0800 UTC.



Key: Filament ___ , Prominence ___ , Magnetic Field Line - - - , Polarity +/-, Coronal Holes: Grey shaded area CHxx +/-, Sunspot groups 25xx - Mt Wilson α-β-βγ-βγδ and Zurich-McIntosh Axx etc.

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Geomagnetic Storms:

The effects of the recent CME arrival have waned early on Day 1 (06 Sep). Although there have been a number of recent large CMEs, there are only a couple that are currently modelled to have a any Earth-directed components. One that may produce a weak enhancement is the 04/1330UTC southeastern quadrant filament eruption. This is expected to be a glancing blow at worst with the bulk of the ejecta expected to pass behind the Earth late Day 2 or early Day 3 (07-08 Sep). A CME in association with a C-flare from south-centre disc on 05/2220 UTC has been analysed as fairly slow but with some Earth-directed component. The arrival time is estimated to be late on Day 4 (09 Sep) with a chance for some enhancement of geomagnetic activity, although there are possible coronal hole influences which could muddy the waters somewhat.

The high speed stream from CH42/+ was forecast to arrive on 05 Sep, however there is no clear signal for this arrival on L1. This may still arrive at some point on Day 1 (06 Sep), but is looking less likely. If winds are to see a rise from CH42/+, they are expected to trend back towards slow-ambient levels going into Day 2 (07 Sep). From late Day 2, but more likely Day 3 (08 Sep) a weak HSS from CH43/- may provide some slight enhancement to solar wind speeds.

In summary, in the absence of any further Earth-directed CMEs, the geomagnetic forecast should show a peak Slight Chance of Active (Kp 4) intervals on Day 1 if any coronal hole influence materialises. There is then a further dampened risk of Active or G1/Minor Geomagnetic Storm intervals from any contribution from CH43/- and/or from the potential CME glancing blow Days 2-3 (07-08 Sep), although both of these events are low confidence and low probability. Towards the end of Day 4 (09 Sep) there is a Chance for Active (Kp4) intervals, with a Slight Chance for G1 Minor Storm (Kp5) intervals in association with a CME arrival. Otherwise, activity is expected to be Quiet to Unsettled (Kp 0-3).

Geo-Magnetic Storm Probability (Exceedance)	Level	Past 24 Hours (Yes/No)	Day 1 (00-24 UTC) (%)	Day 2 (00-24 UTC) (%)	Day 3 (00-24 UTC) (%)	Day 4 (00-24 UTC) (%)
Minor or Moderate	G1 to G2	No	5	5	5	10
Strong	G3	No	1	1	1	1
Severe	G4	No	1	1	1	1
Extreme	G5	No	1	1	1	1

Geomagnetic Activity - Earthbound Coronal Mass Ejections

Date/time 21.5R (UTC)	Halo: Full or Partial	Source	Source Location	Estimated Speed	Estimated Arrival Time	Comments
04/1706	Partial	Plage	SE	980	Early 08 Sep	Glancing blow only
06/0610	Partial	Plage	S-Centre disc	440	Late 09 Sep	Limited impace expected

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Figure 2a: Enlil model showing projected arrival times of CMEs – low confidence for glancing blow early 08 Sep, greater confidence in CME arrival late 09 Sep.

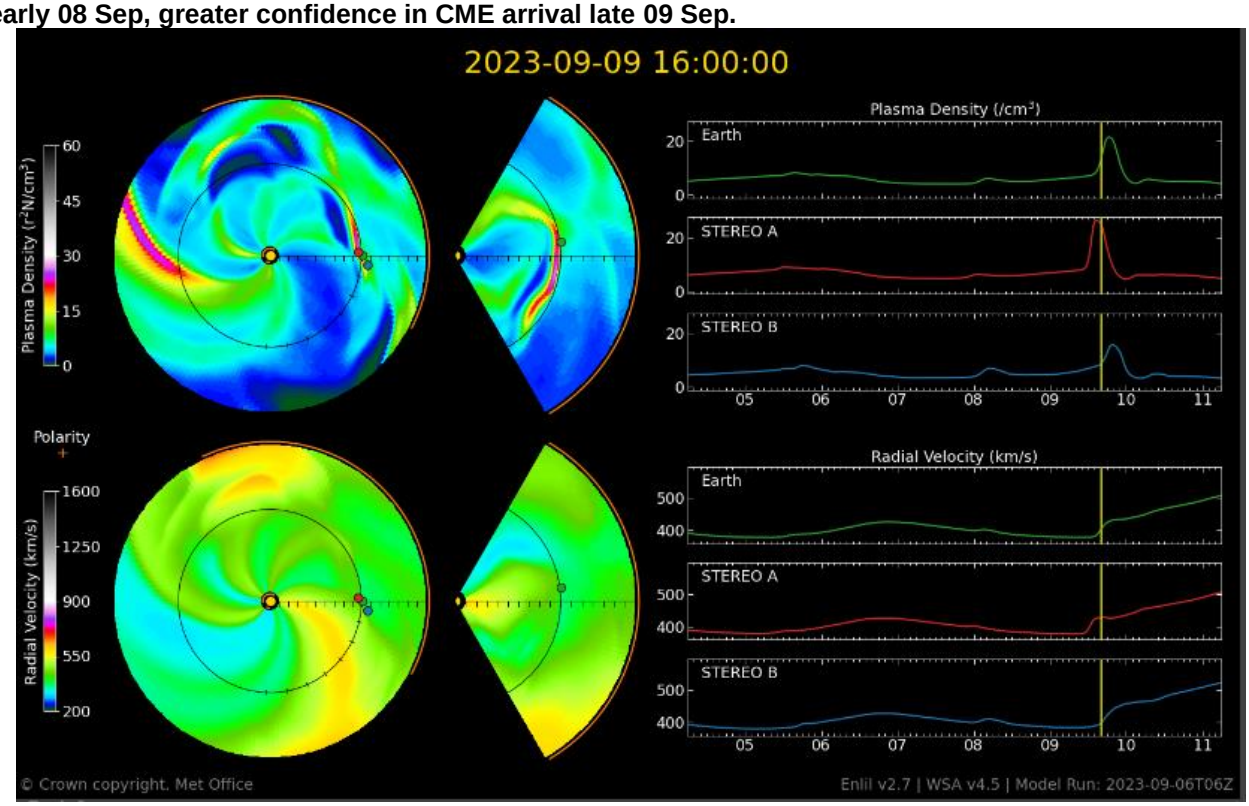
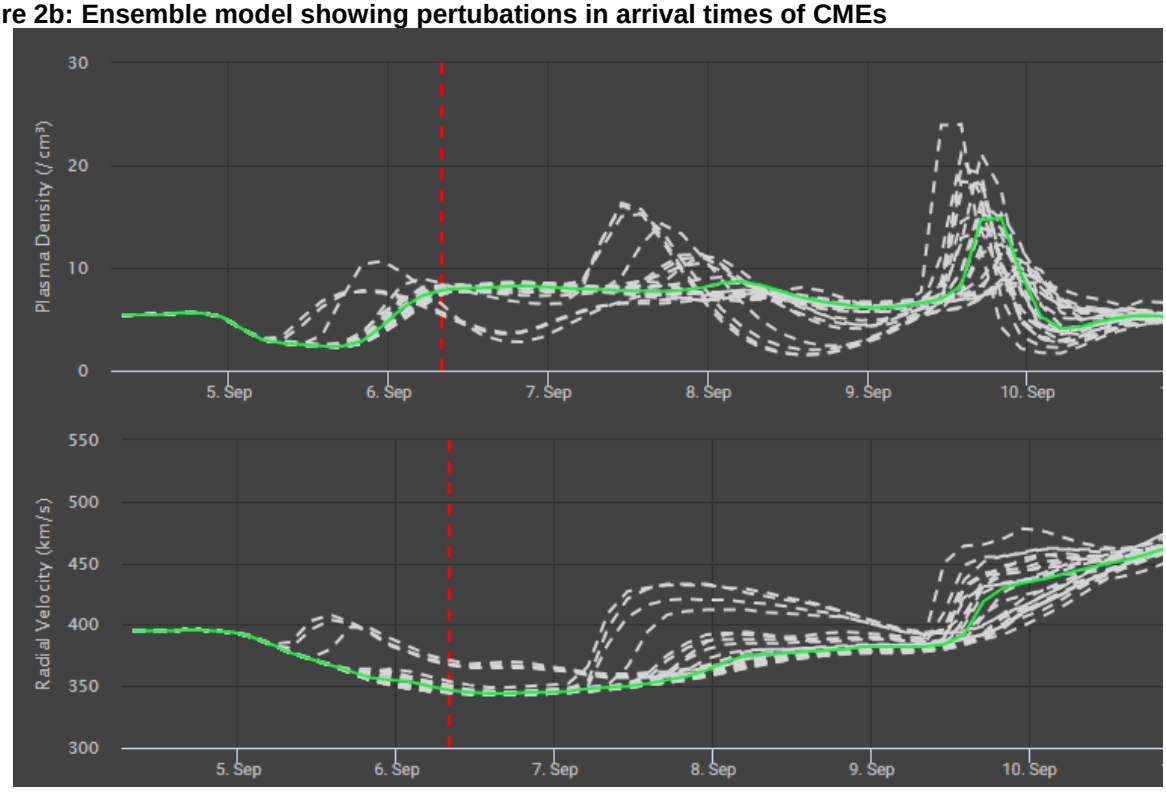


Figure 2b: Ensemble model showing pertubations in arrival times of CMEs



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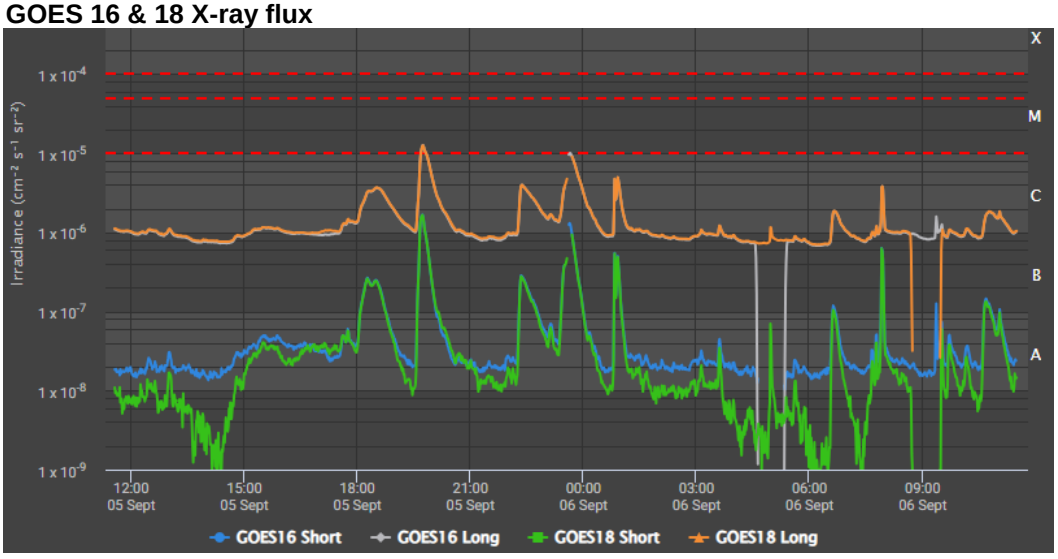
Radio Blackouts - X-Ray Flares:

There are currently seven sunspot regions on the visible disc. The largest and most magnetically complex regions on the disc are AR3421 and AR3423. AR3421 (Eai/Beta-Gamma-Delta), lying along the equator in the west, continues to spread horizontally, with ongoing growth and decay of a number of intermediate spots. A recent intermediate spot in the centre of the sunspot region has developed into a small delta spot. AR3423 (Dai/Beta) continues to grow quite quickly, but currently retains its Beta configuration, although the viewing angle is still limiting. AR3417 (Cso/Beta) in the southwest of the disc has been reclassified given the horizontal extent of the group, but otherwise has shown little change. AR3420 and AR3419 have both faded and are no longer visible. Two new regions have started to emerge across the northeastern limb, AR3424 (Cso/Beta) and another as yet unnumbered (Bxo/Beta), and will be monitored as they rotate further onto the visible disc. One or more of these regions may have been the source of significant flare activity observed from just beyond the eastern limb in recent days.

No significant regions are expected to depart the disc in the period. However, there are signs from far-side soundings, Mars Persistence rover solar images as well as persistence that Ex-AR3403 may have survived its far-side transit and is set to emerge (or continue to emerge) Days 1-2 (06-07 Sep). A further large region may rotate onto the disc by the end of Day 3 (08 Sep).
The sizeable arriving region and the current trend towards increasing flare activity from AR3421 are the reasons for Likely continuation of Moderate X-ray flares initially, and for an increase in flare risk again towards the end of the period as new regions emerge.

X Ray Flares	Level	Past 24 Hours (Yes/No)	Day 1 (00-24 UTC)	Day 2 (00-24 UTC)	Day 3 (00-24 UTC)	Day 4 (00-24 UTC)
Probability			(%)	(%)	(%)	(%)
Active	R1-R2 M Class	Yes	60	40	40	50
Very Active	R3 to R5 X Class	No	2	2	2	2

Figure 3: GOES 16 & 18 X-ray flux



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Solar Radiation Storms - (High Energy Protons):

The high energy (greater than 10MeV) proton flux observed by GOES16 is within Background levels. There has not yet been any response from the recently observed M-class flares, and any exceedance of S1 is considered unlikely.

There is a nominal slowly increasing daily Slight Chance of an enhancement should any significant flares occur, with these most likely from AR3421 and perhaps rapidly-growing AR3423 or newly emerging regions in the north-east.

Radiation Storms Probability (Exceedance)	Level (cm^{-2} sr^{-1} s^{-1})	Past 24 Hours (Yes/No)	Day 1 (00-24 UTC) (%)	Day 2 (00-24 UTC) (%)	Day 3 (00-24 UTC) (%)	Day 4 (00-24 UTC) (%)
Active	**≥ S1**	No	5	2	2	5
Very Active	**≥ S3 ***	No	1	1	1	1
* S3 ≥ 10 MeV ≥ 1000 pfu and / or ≥ 50 MeV ≥ 10 pfu. (pfu = $cm^{-2}sr^{-1}s^{-1}$)						

High Energy Electrons Event (≥ 2MeV):

High energy (greater than 2 MeV) electron flux observed by GOES16 is currently at Moderate levels after a brief period at High levels 05/1525-1720 UTC. Following the recent CME arrival, electron flux levels are expected to attenuate with diurnal oscillations, remaining at Moderate levels. Further enhancements to the electron belt may occur should fast winds arrive from CH42/+ and CH43/-, with a recovery in flux and fluence levels towards the end of the period. However, confidence in detail is currently low for this given up to two incident fast winds, and the potential for a CME arrival later in the period.

The associated 24-hour fluence will most likely remain below the Active (1e8 integrated pfu) threshold throughout the period, but with greatly decreasing confidence with time. MOSWOC REFM is considered to be giving good guidance initially, however, confidence falls through the period given the possible presence of transients.

GEO Electron Environment Probability (Exceedance)	Level (cm^{-2} sr^{-1} day^{-1})	Past 24 Hours (Yes/No)	Day 1 (00-24 UTC) (%)	Day 2 (00-24 UTC) (%)	Day 3 (00-24 UTC) (%)	Day 4 (00-24 UTC) (%)
Active	**≥ 2 MeV ≥ $1x10^8$**	No	5	10	20	20
Very Active	**≥ 2 MeV ≥ $1x10^9$**	No	1	1	1	1

Figure 5a: GOES 16 Electron flux

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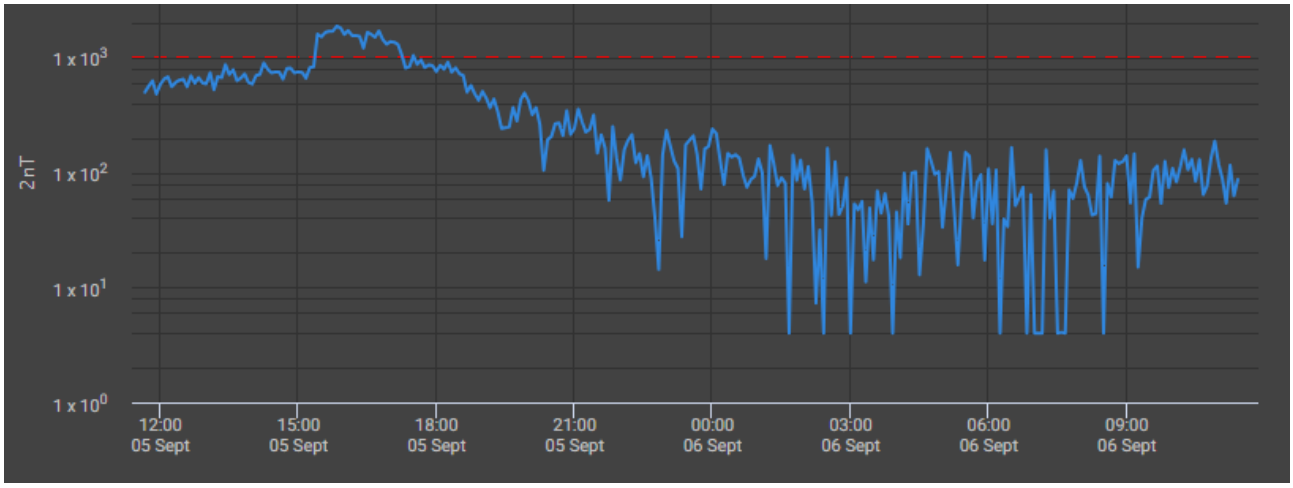
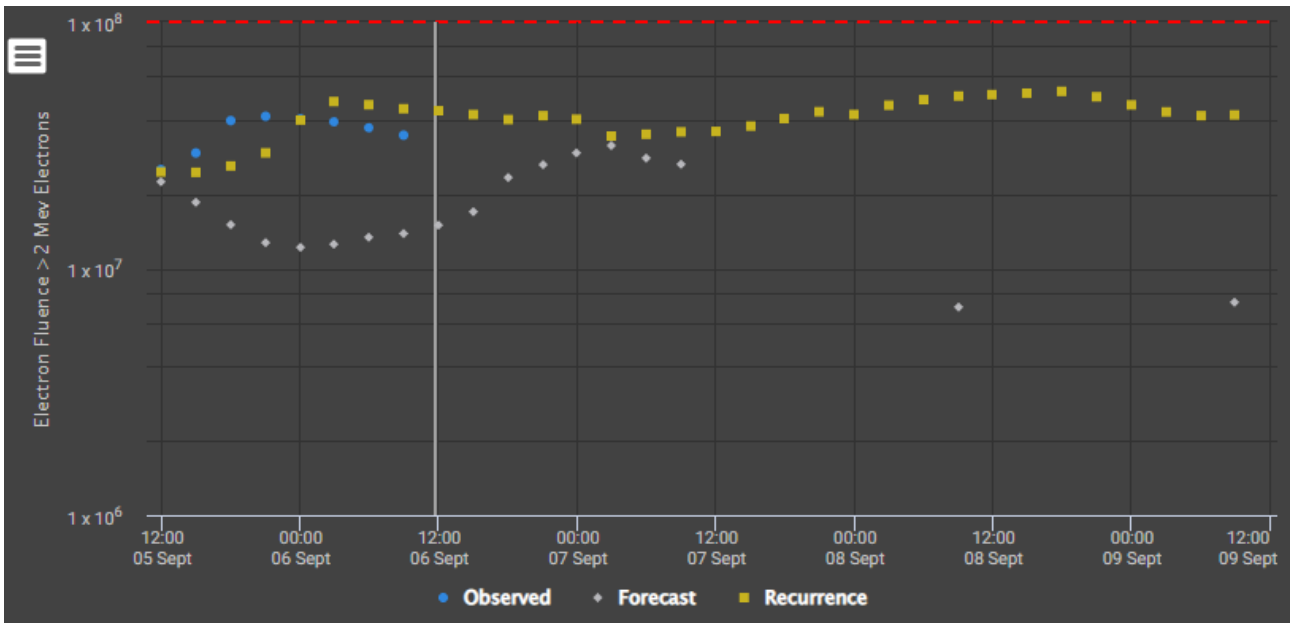


Figure 5b: REFM showing observed, forecast and recurrance electron fluence.



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